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ABSTRACT

This booklet presents some activities to measure various weather phenomena. Directions for constructing a weather station are included. Instruments including rain gauges, thermometers, wind vanes, wind speed devices, humidity devices, barometers, atmospheric observations, a dustfall jar, sticky-tape can, detection of gases in the air, and pH of rain water are illustrated using sample activities. (KHR)

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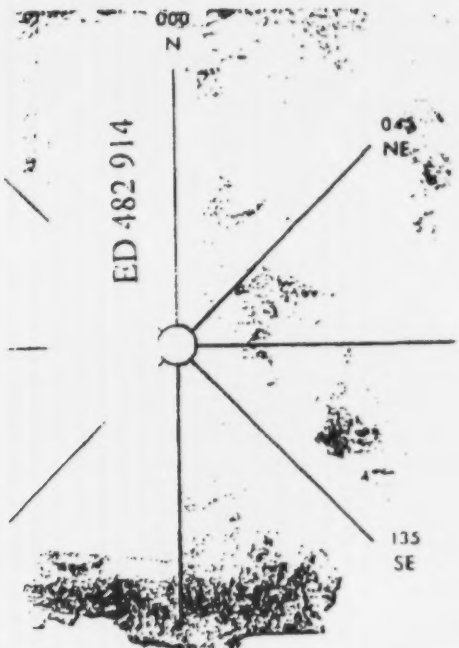

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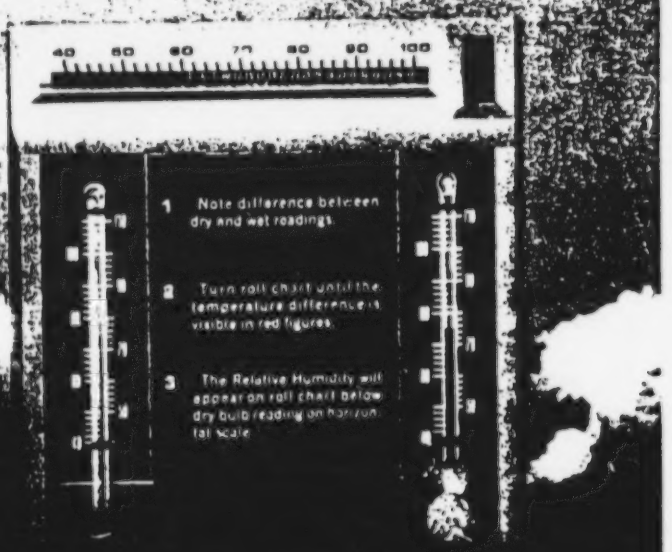
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1 Note difference between dry and wet readings.
2 Turn roll chart until the temperature difference is visible in red figures.
3 The Relative Humidity will appear on roll chart below dry bulb reading on horizontal scale.

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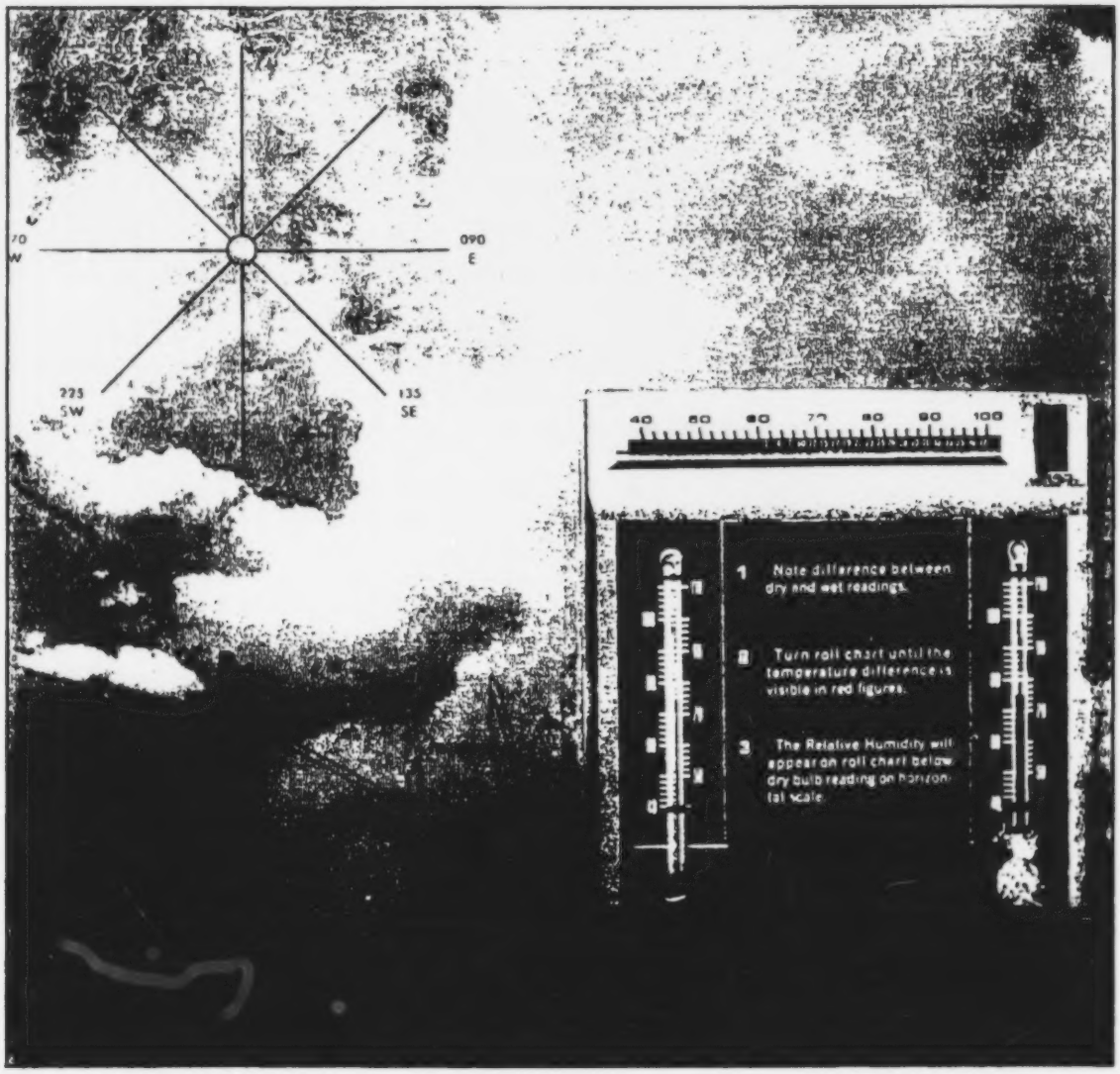
270
W
090
E
225
SW
135
SE
40 50 60 70 80 90 100
1 Note difference between dry and wet readings.
2 Turn roll chart until the temperature difference is visible in red figures.
3 The Relative Humidity will appear on roll chart below dry bulb reading on horizontal scale.

Foundational Approaches in Science Teaching
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The Weather Station

The *weather station* is a box or platform which holds weather instruments. Some stations may be located at home, on the campus, or in other places available to you. One should be in your Class Study Area.

Materials

- a box which can withstand rain and winds
- a secure post or other support on which to put the box
  (This foundation must not wobble or move.)

Directions

1. Select a location for the station.

   a. Locate the station at least 1 meter above ground or on a roof. Weather Service rain gauges are set about 1 meter above the ground. Wind instruments are usually placed about 30 feet above the ground or high enough to be well above nearby obstructions. Other devices are set wherever conditions indicate.

   b. Set your station as far away from trees and buildings as possible. Trees and buildings may affect the wind patterns and rain measurement. Avoid wind channels between tall buildings.

   c. If all of these conditions cannot be met, select the best location you can find.

2. Make a site map of the location of your station. An example of a site map is shown in Figure 1.

   a. On a blank paper, sketch a rough map showing the area in which your weather station is located. Place your station at the center of the site map.

   b. Pace off the distances in eight compass directions to obstructions higher than 1 meter. Indicate their heights and distances on the site map.

   c. Keep your site map with your data sheet. The sight map shows what objects might affect your weather measurements.

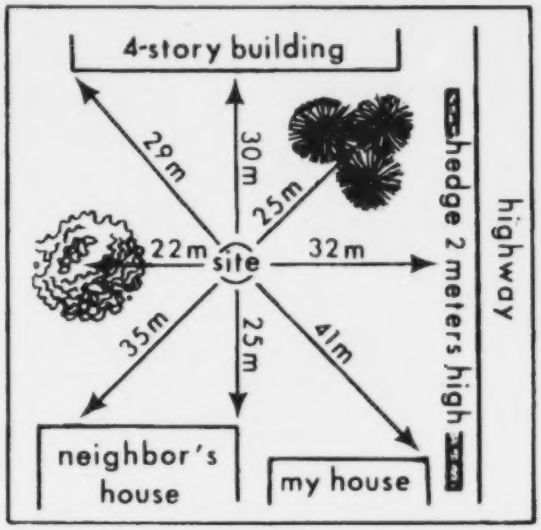


Figure 1 Sample site map.

3. Construct the weather station.

   Two ideas for construction of a weather station are shown in Figure 2. You may think of others suitable to your particular location and the instruments you choose to use.

   a. The station should have a top which is exposed to the sky to hold rain gauges and a weather vane.

   b. Each weather station should have a sheltered section to protect some instruments from rain and sun, yet allow free passage of air.

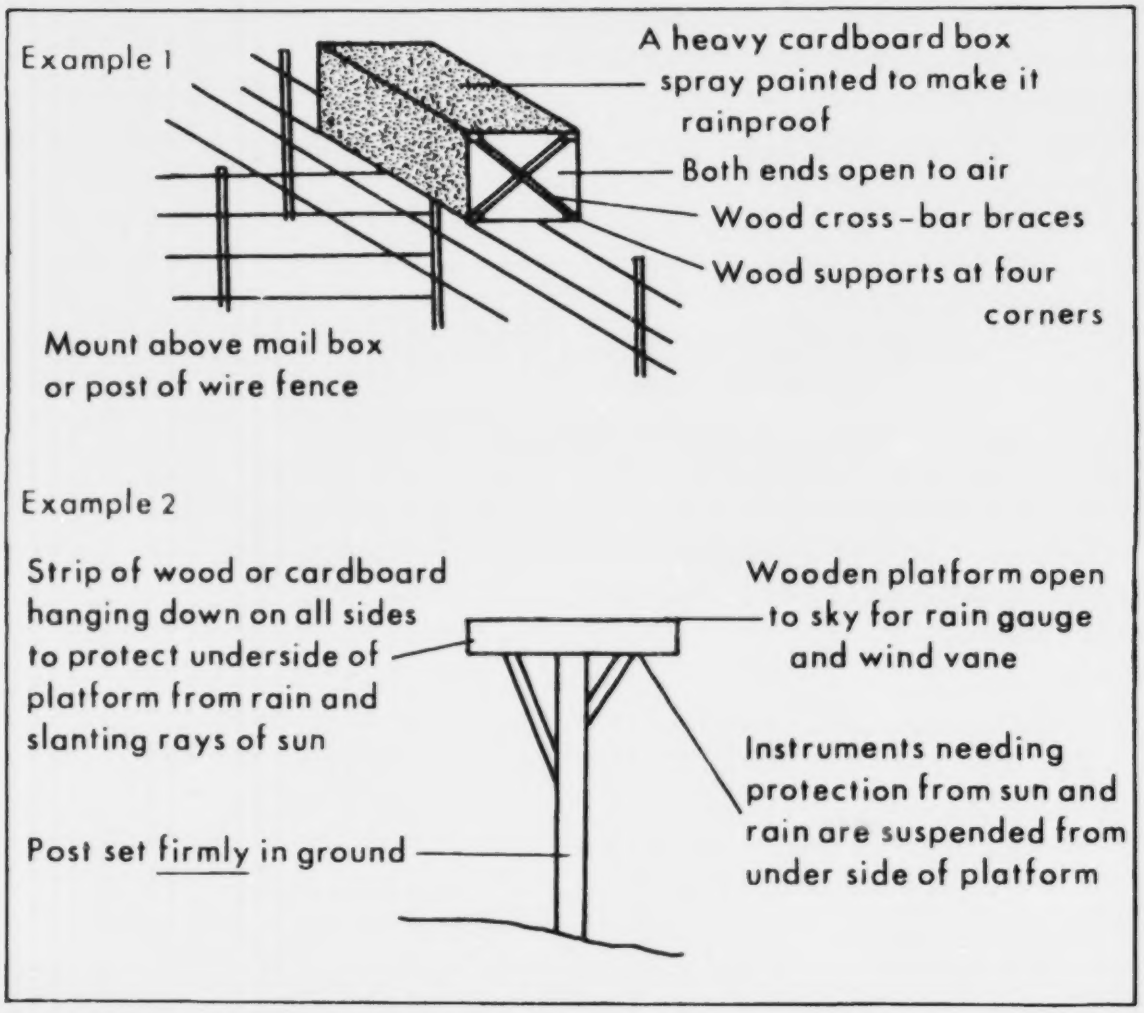

Example 1
A heavy cardboard box spray painted to make it rainproof
Both ends open to air
Wood cross-bar braces
Wood supports at four corners
Mount above mail box or post of wire fence
Example 2
Strip of wood or cardboard hanging down on all sides to protect underside of platform from rain and slanting rays of sun
Wooden platform open to sky for rain gauge and wind vane
Instruments needing protection from sun and rain are suspended from under side of platform
Post set firmly in ground

Figure 2 Two weather station designs.

Rain Gauges

Three types of rain gauges are described. Choose the kind which seems suited to your needs.

Type A. The Daily Rain Gauge

Materials

- 6 oz. juice can
- ruler

Construction

1. Construct the gauge as shown in Figure 3.
2. Place the gauge on top of your weather station. Fasten the can so that it will not blow over, but can be removed and emptied daily.

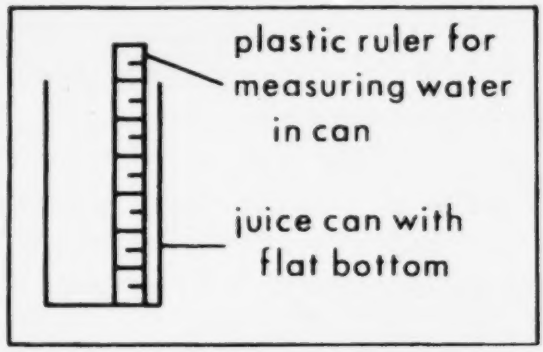


Figure 3 Daily Rain Gauge.

Use of the Daily Rain Gauge

1. Once each day, hold the ruler upright in the can and measure the depth of water.
2. Record the depth.
3. After measuring, empty the can and replace it on the station.

Type B. The Storage Rain Gauge

The *Storage Rain Gauge* is used for measuring rainfall from a single storm lasting several days or for measuring weekly rainfall.

Materials

- a tall straight-sided can (about 16 cm tall)
- 5 ml of heavy motor oil
- ruler

Construction

1. Put a thick layer of heavy motor oil in the can. The oil prevents water from evaporating from the gauge.
2. Put water into the can and adjust the oil and water to a depth of about 3 cm. Record the starting depth.
3. Place the gauge on top of your weather station facing the open sky. Fasten the can so that it will not blow over but can be removed and emptied. (See Figure 4.)

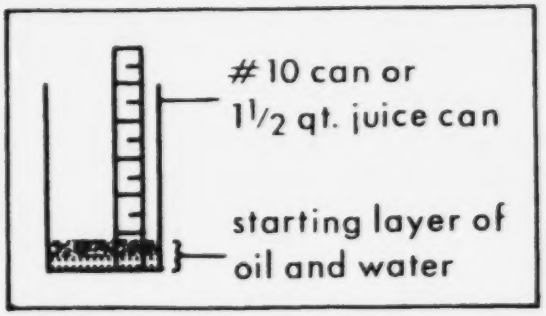


Figure 4 Storage Rain Gauge

Use of the Storage Rain Guage

1. After a heavy storm, or after a week of lighter rain, insert a ruler into the can and measure the depth of the water. Subtract the starting depth from this measurement. Record the amount of rainfall.
2. Empty the gauge by tipping it gently sideways and pouring off nearly all the water. Hold back as much oil as possible with the edge of a ruler. Some water should be left in the bottom of the can.
3. To continue taking measurements, reset the level of oil in the gauge to the starting depth.
4. Clean the ruler after use.

Type C. The Light Rain Gauge

The *Light Rain Gauge* is used to measure rainfall too light to be accurately recorded in the Daily Rain Gauge.

Materials

- plastic lid or cardboard
- sheet of aluminum foil
- jar (peanut butter size)
- vial
- straight-sided, flat-bottomed can

Construction

1. Select a straight-sided, flat-bottomed can to use as a *calibration* can.
2. Construct a funnel from a plastic lid or light cardboard. The top diameter of the funnel must be the same as the diameter of the calibration can.
   a. Cut from the edge to the center of the lid or cardboard.
   b. Cut a hole out of the center about 1 cm in diameter.
   c. Cover the cardboard with aluminum foil (if using plastic, it need not be covered).
   d. Fold the circle into a funnel shape and fasten it together with staples.
3. Put the small vial into the jar. Place the funnel on top of the jar with its center hole reaching into

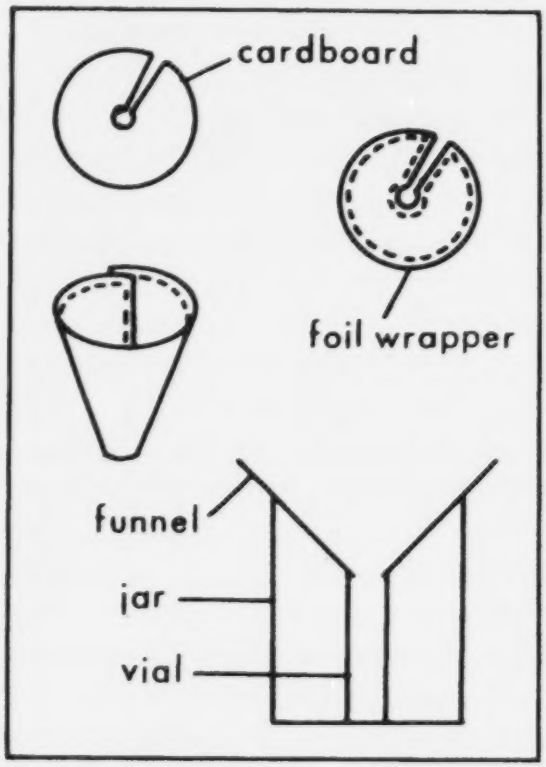


Figure 5 Construction of Light Rain Gauge

the vial. (The jar may be any shape or size. Its function is to hold the small vial and support the funnel.) (See Figure 5.)

4. Place the gauge on top of the weather station facing the open sky. Anchor it securely so that it does not blow away.

Calibration of the Light Rain Gauge

1. Fill the small vial with water.
2. Empty the water from the vial into the calibration can.
3. Do this 10 times to increase the depth of water in the calibration can to a more accurately measurable amount.
4. Measure the depth of water in the calibration can and divide by 10. This number tells you the measurement of rainfall when the vial is full.

   Example: If one full vial of water comes to a depth of 0.8 cm in the calibration can, then the full vial = 0.8 cm of rainfall, even though the vial itself is much taller than 0.8 cm.

5. Mark the vial at ½ and ¼ distances and indicate the equivalent rainfall values for these marks. (See Figure 6.)

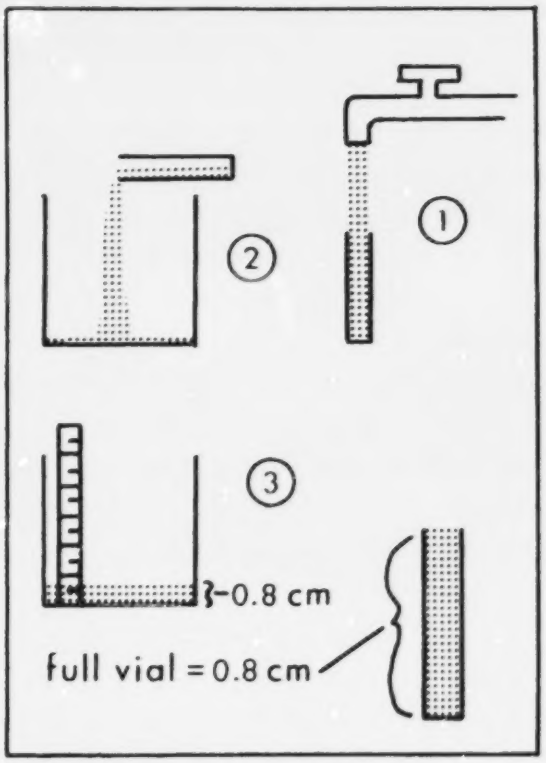


Figure 6 Calibration of Light Rain Gauge

Use of the Light Rain Guage

1. Read the gauge daily according to the markings on the vial. If the rain collected is too little to measure, record "trace" on your data sheet.
2. If the rain overflows the vial, it cannot be measured by the type C gauge without further special calibration. Readings for heavier rains are made from types A or B gauges.

Explanation of the Operation of Rain Gauges

A visiting class from the planet Mars has joined your class in an earth weather project. Some of the Martian students are having difficulty understanding the operation of their rain gauges. Can you take over as teacher of the class and explain matters to them? Here are their problems and opinions.

1. Rainfall is measured by the type A and B gauges by inserting a ruler and noting the depth of the water. A ruler measures linear distance. Yet the rainwater in the can occupies a volume. Several of the Martians wonder how a linear measurement can indicate amount of rainfall. Can you explain it?

2. Martia May's rain gauge is a juice can two inches in diameter and four inches tall. Marto Joe's gauge is eight inches in diameter and four inches tall. Both gauges were put out in the same rain for the same length of time. May collected 20 ml of water which came to a depth of 1 cm. Joe collected 150 ml of water which came to a depth of 1 cm. Joe claims he caught more water than May. May claims both gauges measure the same rainfall. Who is right? (See Figure 7.)

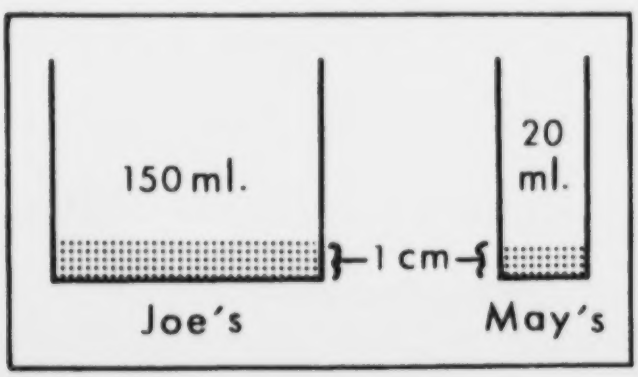


Figure 7 Joe's and May's rain gauges.

3. Marto Tom thinks Earth Being should make all rain measurements in centimeters. He thinks inches should be banned. What is your opinion?

4. Marto Tim says he is using a drinking glass as a rain gauge. He can see the height of the water much better than in a can.

Martia Mil is using a gallon glass jar.

Are these containers acceptable? Why or why not? (See Figure 8.)

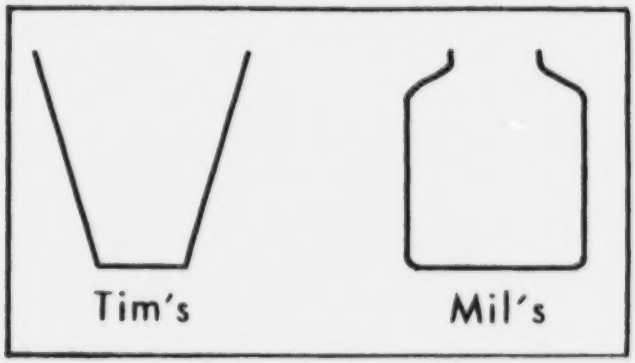


Figure 8 Tim's and Mil's rain gauges.

5. Marto Ron left his type C gauge in a heavy rain. The vial flowed over into the jar. He poured all the water from both the vial and the jar into his calibration can and measured its height. He claims this is the measure of the rainfall caught by his type C gauge. Is it? Why or why not? (See Figure 9.)

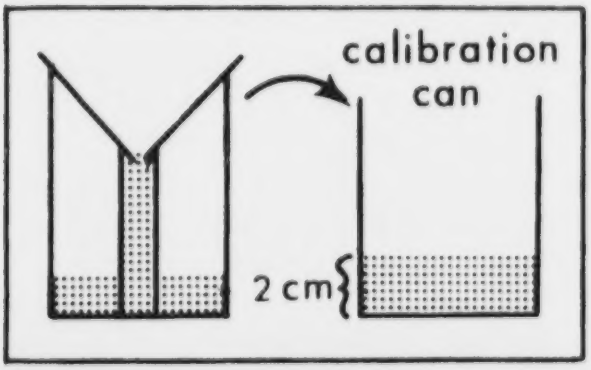


Figure 9 Ron's rain gauge.

6. Ron has a Martian friend who is always trying to do him one better. The friend also had an overflow in his type C gauge. Even though his jar has uneven sides, he says he can measure rain with it. He had the whole jar calibrated, he says, by pouring into it 1 cm, then 2 cm, then 3 cm of water from the calibration can and marking the level of each amount. Will this give reliable rainfall measurements? (See Figure 10.)

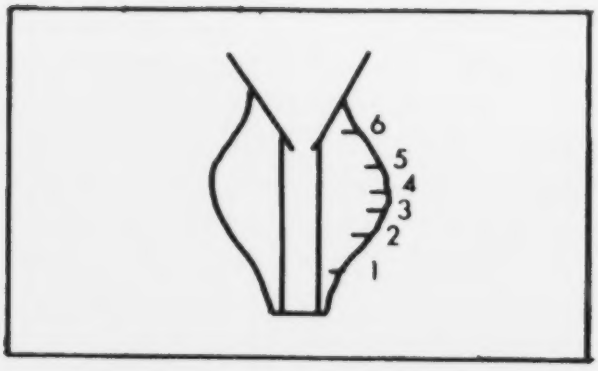


Figure 10 Gauge with uneven sides.

7. Two Martian girls put their storage gauges under a big tree. They claim they are getting rain measurements which would apply to a forest and they want their data to go on the chart with everyone else's. Is this acceptable?

Thermometers

For measuring temperatures at your Weather Station, you may use either a *Fahrenheit thermometer* or a *Celsius thermometer.*

Keep the thermometer safely in the house or underneath the platform. Bring it out to the weather station only when you wish to make a reading. (Durable, out-of-doors thermometers can be left outside in the covered part of your station, protected from the sun.)

Using the Thermometer

1. When you go out to do your weather readings, lay the thermometer safely on, or in, the weather station box in the shade. If your weather station is not well ventilated, lay it in the shade elsewhere but with the bulb not touching any object. Let the thermometer adjust to the local temperature while you do your other readings.
2. Pick up the thermometer without touching the bulb. Read it once, quickly, to the nearest degree and record that temperature. If you take too long to read it, the heat from your breath and body will raise the temperature. You may take a second reading as a check on accuracy after returning it to the shaded position for at least one minute.
3. If you have one kind of thermometer and the class standard requires that you turn in data in the other system, use the conversion scale in Figure 11 to convert your readings to the desired system.

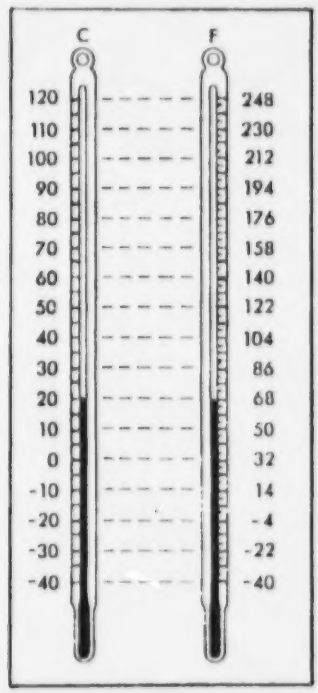


Figure 11 Comparison of Fahrenheit and Centigrade (Celsius) temperature scales.

Wind Vanes

A *wind vane* measures the direction from which wind comes. A wind blowing *from* the northeast *towards* southwest is a northeast wind. (See Figure 12.)

Materials

- a pointer made of waterproof material and stiff enough to hold up in the wind
- a flat baseboard about ¾- to 1-inch thick
- a very large, long nail (about 10 cm)
- a tiny test tube (about 6-ml capacity)
- a compass
- a direction pattern or template (page 15)

Construction

1. Drive the nail through the board with the point extending upward. The nail must be straight and not wobble.
2. Place the template for wind direction on the baseboard with the nail puncturing the center of the template.
3. Place the compass on the baseboard and turn the pattern until north on the pattern matches north as it appears on the compass.

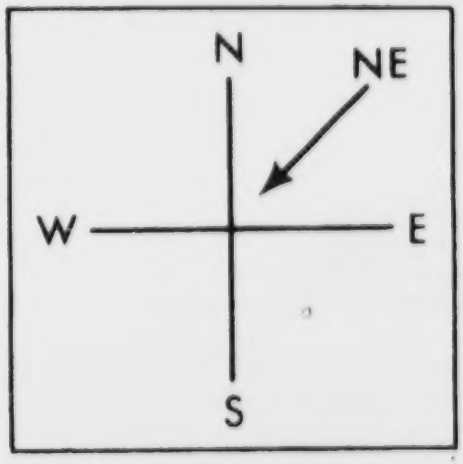


Figure 12 Record direction wind comes from.

4. After your weather station is secure and does not wobble or turn, glue the direction template to the base. Thereafter, you do not need the compass except to check whether the station may have moved or turned.

5. Make the pointer. The pointer may be various sizes and shapes and made of any rain-proof, strong material. Be sure of each of the following:

   a. One end of the pointer is *small and heavy.*

   b. The other end of the pointer is made of lightweight material with a *large surface area.*

   c. The *total mass* of the small end equals the *total mass* of the large end of the pointer. That is, the *total mass* of each of the two ends is the same. (See Figure 13.)

6. Attach the pointer to the test tube. The pointer should be balanced on the test tube.

7. Set the test tube and wind vane on the nail. The wind vane should swing freely and easily. (See Figure 14.)

   The wind blows on the large end of the pointer and swings it around making the small end face into the wind. If the *vane points to the southwest* the wind is *coming from the southwest. It is a southwest wind.*

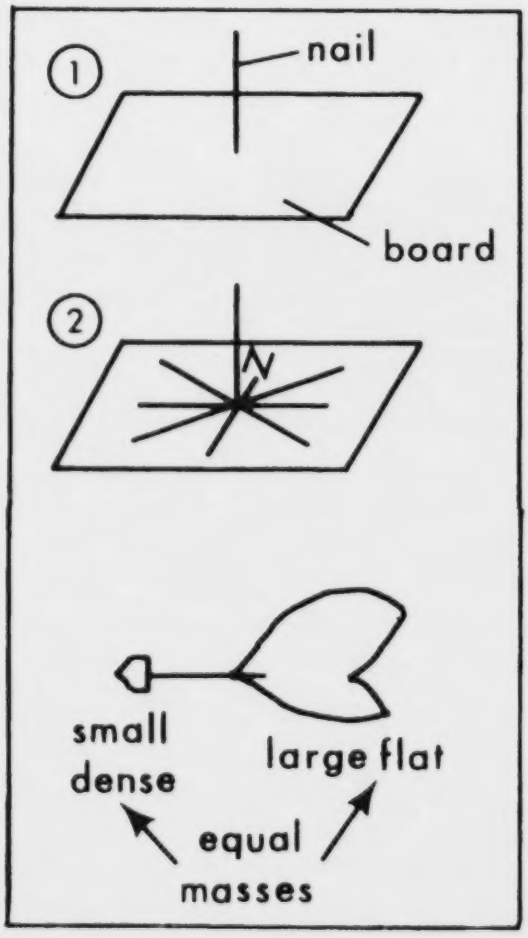


Figure 13 Construction of a wind vane.

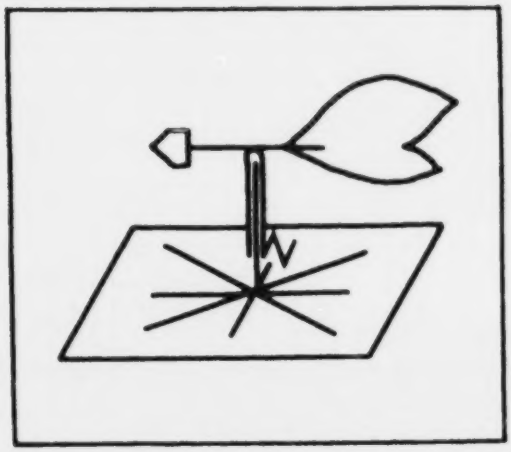


Figure 14 A finished wind vane.

Use of the Wind Vane

1. Wind does not blow evenly. It comes in gusts. Watch the wind vane for about 1 minute to determine which of the 8 compass directions it points to most of the time. Record that direction as the reading.
2. If the wind is so erratic that the pointer swings over 180° and keeps turning, record 999 as your wind direction. The symbol 999 means that the wind direction cannot be determined.
3. If your data is to be used on a computer, the compass directions should be reported as numbers instead of letters. The numbers, as well as the letters, are given on the template. (See Figure 15.)

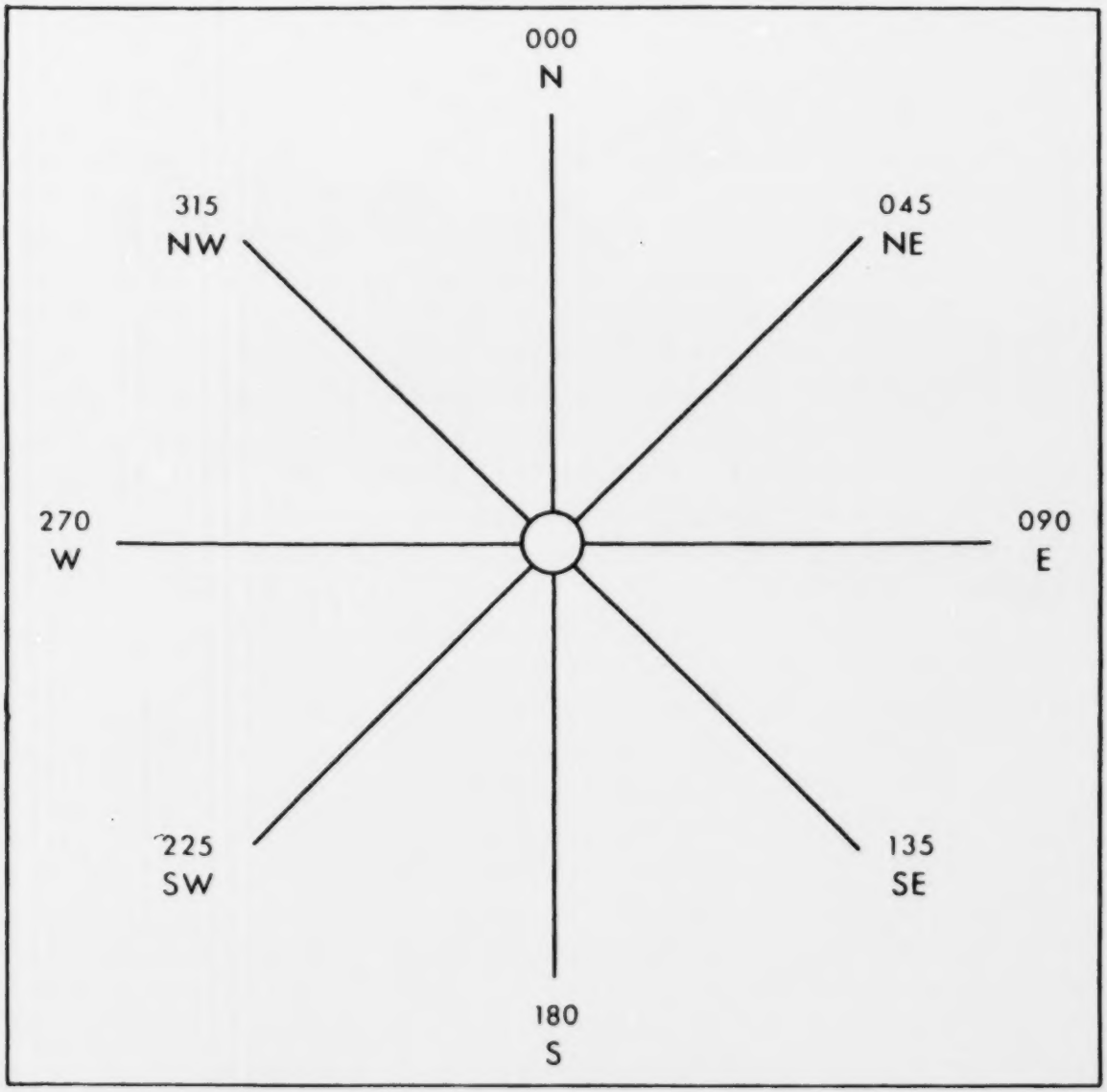


Figure 15 Template for wind direction.

Wind Speed Devices

An *anemometer* is an instrument which measures wind speed. Three ways of determining wind speed are described below.

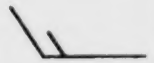
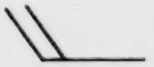
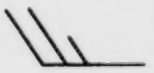
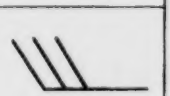
Type A. Sensing the Wind

One way to measure wind direction and wind speed is to rely on your own senses instead of instruments. Skill in using your senses to estimate wind can be very useful. For example, you can observe wind effects in treetops from the ground. You may sense the wind on your way to school or on a hike when you do not have your anemometer with you.

Directions

1. Determine the wind direction. Stand so that the wind strikes you directly on the face, i.e., face into the wind. With a pocket compass, or by known landmarks, or by the stars, determine which way you are facing.
2. Estimate the wind speed. Observe how the wind moves objects within your sight. Compare the effects you see with effects described in Table 1, Sensing Wind Speed. With much practice, you will remember the effects and not have to carry the table with you.
3. Record your observations in any of five ways: the Weather Service symbol, a descriptive word, miles per hour, meters per second, or the Beaufort number. The Beaufort number is a rating of wind force ranging from 1 to 12 or higher and is often used in meteorology.

Table 1 Sensing Wind Speed

Wind Effects Observed on Land	Terms used in Forecasts	Beaufort Number	Meters per second	Miles per hour	Weather Service Symbol
Calm; smoke rises vertically. Direction of wind shown by smoke drift but not by wind vanes.	light	1	0 – 1	0 – 2	
Wind felt on face. Leaves rustle. Ordinary vane moved by wind.		2	2 – 3	4 – 6	
Leaves and small twigs in constant motion. Wind extends flag.	gentle	3	4 – 5	8 – 12	
Raises dust and loose paper. Small branches moved.	moderate	4	6 – 7	14 – 16	
Small trees with leaves begin to sway. Whitecaps form on waters.	fresh	5	8 – 10	18 – 22	
Large branches in motion. Whistling heard in wires between utility poles. Umbrellas used with difficulty.	strong	6	11 – 14	24 – 30	
Whole trees in motion. Inconvenience felt in walking against wind.	gale	7	15 – 18	32 – 40	

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Type B. Cup Anemometer

The Weather Service measures wind speed with a *cup anemometer*. A cup anemometer is a set of cups on a pivot. As the wind turns the anemometer, each turn is counted electrically and registered on a dial.

The following are directions for making a homemade version of the official cup anemometer.

Materials

- four cone-shaped paper cups
- aluminum pie pan or large plastic coffee can lid
- small test tube
- watch

Construction

1. Fasten four paper cups around the aluminum pie pan or similar base as shown in Figure 16.
2. Insert a small test tube through the center of the pie pan. This becomes the same kind of pivot as was used on the wind vane.
3. Use one cup with a color different from the others. The colored cup is easier to see when counting turns of the anemometer.
4. Mount the anemometer on the nail used for the wind vane.

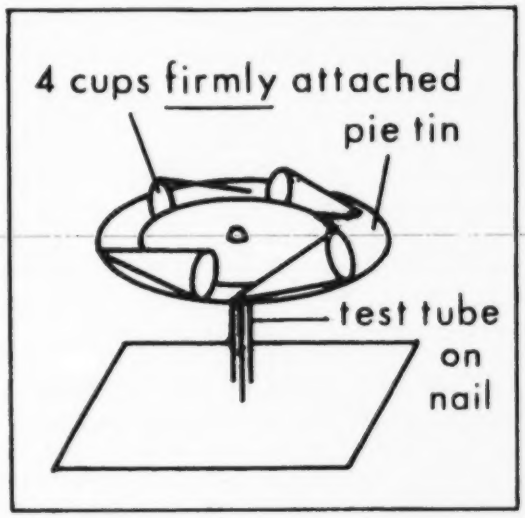

Figure 16 A cup anemometer.

Calibration of the Cup Anemometer

Wind speed is measured either in miles per hour or meters per second. To obtain accurate measurements your homemade cup anemometer must be calibrated against a standardized instrument such as the Taylor Cup Anemometer.

1. Set up a wind tunnel. Use cardboard or boxes to make a wind tunnel about 1 meter long. Place a powerful 3-speed fan at one end of the tunnel.

2. Put the standardized instrument at the other end of the wind tunnel. Position the standardized instrument where it receives a steady wind. (See Figure 17.)

3. Mark the spot where the standardized instrument is placed. Also record the height of the cups of the standardized instrument above the table or floor.

4. Set the fan at low speed. Determine the wind speed in the tunnel by reading the dial of the standardized instrument. Record the wind speed in meters per second or miles per hour.

   Caution: Do not have any drafts in the room as they may affect the wind speed reading.

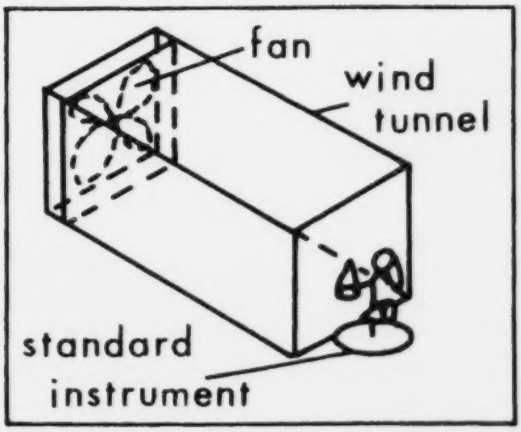

Figure 17 Homemade wind tunnel.

5. Remove the standardized instrument from the wind tunnel. Place your homemade cup anemometer in the *exact* spot the standardized instrument occupied. Be sure the height of the cups is the same as that of the standardized instrument. (See Figure 18.)

6. In this known wind speed, count how many revolutions per minute (rpm) your cup anemometer makes. Repeat the counting three times. Record the average rpm's your cup anemometer makes with the fan on low speed.

7. Repeat steps 2 to 6 with the fan at medium speed and at high speed.

8. Make a calibration graph. Use the horizontal axis for rpm's from your cup anemometer. Use the vertical axis for the corresponding wind speed recorded from the standardized instrument. (See Figure 19.)

Use of the Cup Anemometer

1. Mount your cup anemometer on the weather station.
2. Count the number of revolutions your cup anemometer makes in one minute. Record the rpm's.
3. Use the calibration graph to determine the wind speed. For example, suppose you count 120 rpm's on your cup anemometer.
   a. Find 120 rpm's on the horizontal axis of the calibration graph.
   b. Determine the corresponding wind speed from the intersect on the graph.
   c. In the example shown below, 120 rpm's would be equivalent to 7.5 meters per second.

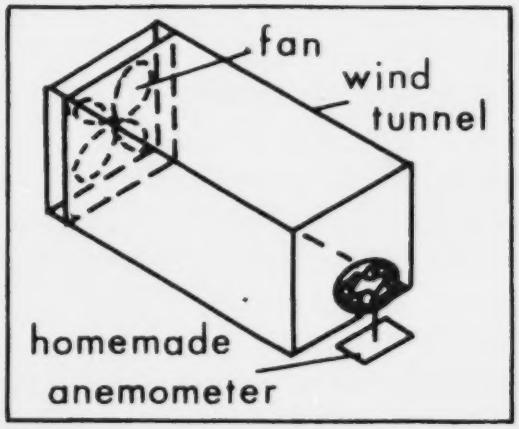

Figure 18 Calibrating the cup anemometer.

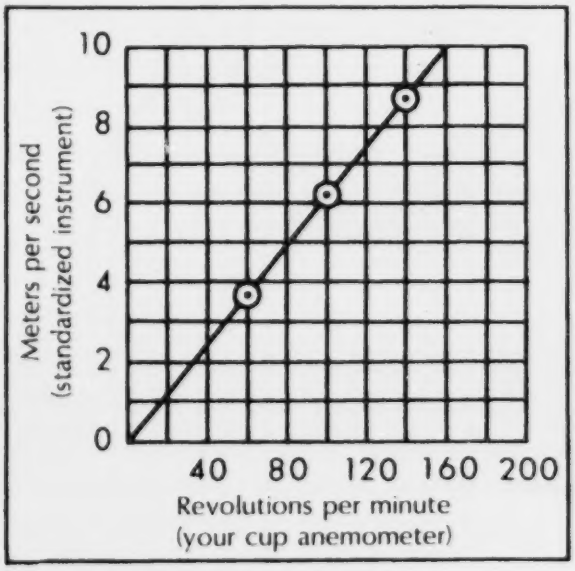

Figure 19 Calibration graph.

Type C. Pendulum Anemometer*

A homemade anemometer which is already calibrated is the *pendulum anemometer.*

Materials

- a dowel, curtain rod, or flat wooden slat about 30 cm long
- a plastic protractor, 15 cm diameter
- large-bore glass tubing 6.5 cm long, inside diameter 0.5 cm or larger
- a sewing needle, between 6.0 and 6.5 cm long
- monofilament "invisible sewing thread" or lightweight monofilament fish line about 40 cm long
- an official regulation table tennis ball
- string about 3 cm long which will go through the eye of the needle
- airplane cement

Construction

The steps are listed here in an order which allows the glue to dry on one part while you work on another part of the assembly. (See Figure 20.)

1. Glue the glass tubing to the calibrated side of the protractor so that it fits between the hole in the center of the protractor and the 90° mark.
2. Thread the needle with about 40 cm of monofilament thread. Push the needle through two poles of the table tennis ball. Pull the thread through the ball. Then unthread the needle and fasten one end of the thread to the ball with a *small* bit of glue.

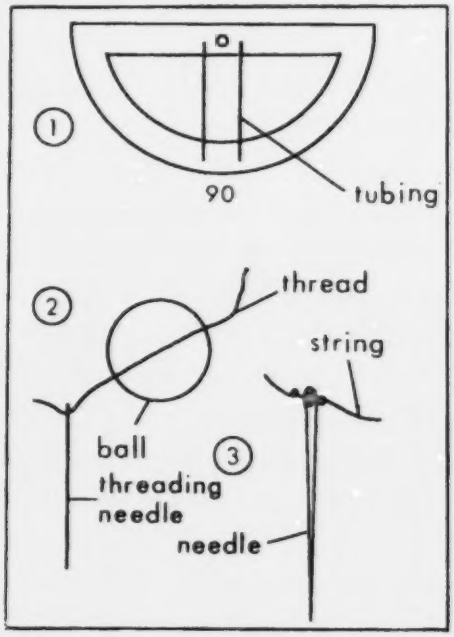

Figure 20 Preparing a pendulum anemometer.

* Modification of a design by Dr. Patrick Clemens, Arnold Research Organization. Original design reported in *Scientific American*, 225:4, October 1971.

3. Thread 3 cm of string through the needle. If the thread slips easily through the eye, put a knot on both sides of the eye. Allow the needle to swing freely on the string without slipping along the length of the string.

4. Check to be sure the glass tubing is firmly attached to the protractor. Pick up the protractor. Stretch the string across the top of the glass tubing and let the needle hang down *inside* the tubing. The eye of the needle should be just below the hole in the protractor. Fasten the string securely to the tubing.

5. Take the other end of the thread which has the ball at one end and thread it through the hole at the top of the protractor. Let the thread and ball hang on the smooth side of the protractor. (If it is on the calibrated side the thread catches in the protractor markings.)

6. Fasten the thread so that the distance between the hole in the protractor and the top of the ball is *exactly 30 cm*. Fasten the thread so that it does not slip to a different distance. Blacken a spot on the thread where it crosses the protractor angle to make it easier to read.

7. Attach the protractor to the middle of the dowel or slat. This gives you a handle for holding the pendulum steady. Be careful not to cover the hole of the protractor with the slat or interfere with the free swing of the thread. (See Figure 21.)

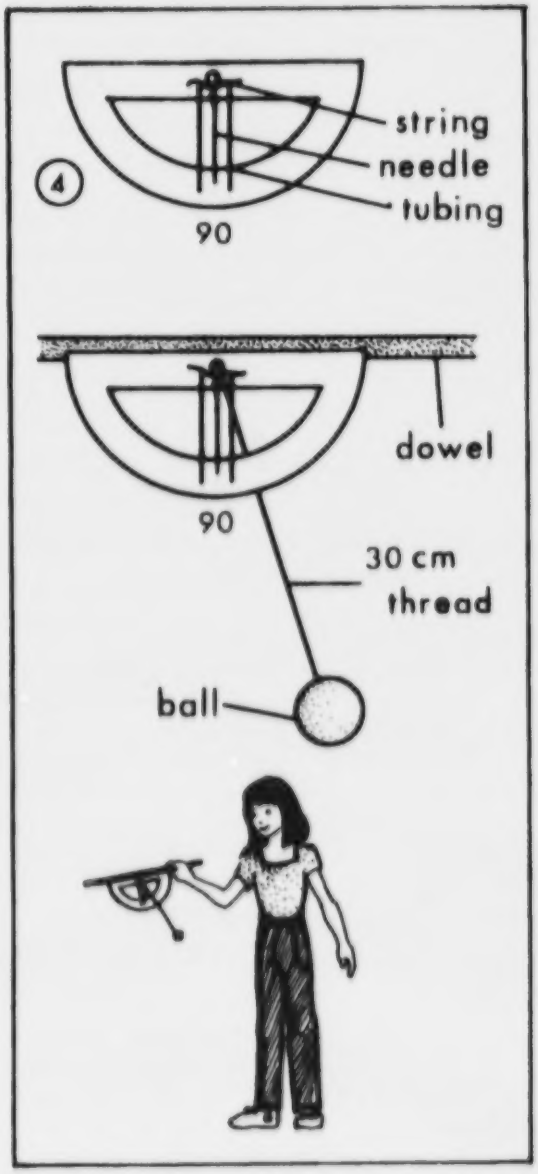

Figure 21 Construction and use of a pendulum anemometer.

Use of the Pendulum Anemometer

1. Hold the anemometer in front of you at arm's length. Stand so that the wind comes to you from one side. This keeps your body from interfering with wind currents.

2. Hold the anemometer so that you can read the protractor. Keep the needle hanging free and centered over the 90° mark.

3. The wind will blow the ball and thread along the arc of the protractor. Observe the reading on the protractor where the thread crosses the lines of the protractor. Watch for about 1 minute because winds are gusty. Decide the reading to which *most* of the gusts push the thread.

4. Using the following table, find the wind speed corresponding to the reading. Record the wind speed using any one of the three measuring systems shown in Table 2.

Table 2 Wind Speed Using the Pendulum Anemometer

Reading on Protractor	Miles per Hour	Meters per Second	Computer Data (105 = 10.5 meters/sec)
90	0.0	0.0	000
89	2.5	1.2	010
88	3.5	1.6	015
87	4.5	2.0	020
85	6.0	2.5	025
83	7.0	3.0	030
81	8.0	3.5	035
78	9.0	4.0	040
75	10.0	4.5	045
72	11.0	5.0	050
69	12.0	5.5	055
65	13.5	6.0	060
61	14.5	6.5	065
57	15.5	7.0	070
54	16.5	7.5	075
50	18.0	8.0	080
47	19.0	8.5	085
43	20.0	9.0	090
40	21.5	9.5	095
37	22.5	10.0	100
35	23.5	10.5	105
32	25.0	11.0	110
30	26.0	11.5	115
28	27.0	12.0	120
26	28.0	12.5	125
24	30.0	13.0	130
less than 24	—	—	999

Humidity Devices

To measure humidity, use any of the humidity devices described below.

Type A. Cobalt Chloride Indicators

Humidity cards are often placed in boxes containing precision instruments sealed in moisture-proof plastic. Manufacturers seal the cards in the boxes so that the receiver will know if the box has been broken in shipping. If the sealed container has been broken, the humidity card will show a high relative humidity.

Paper strips saturated with cobalt chloride are used to make these humidity cards. Cobalt chloride is a chemical which is pink when it is wet and blue when it is dry. The humidity cards are sensitive to a 5% to 10% change in relative humidity.

Materials

- a humidity card

Use of the Humidity Card

1. The humidity card changes color from blue to pink as the relative humidity increases.
2. Locate the area on the humidity card which seems to change from blue to pink.
3. Read the indicated relative humidity. The card is accurate to within 10% relative humidity. (See Figure 22.)

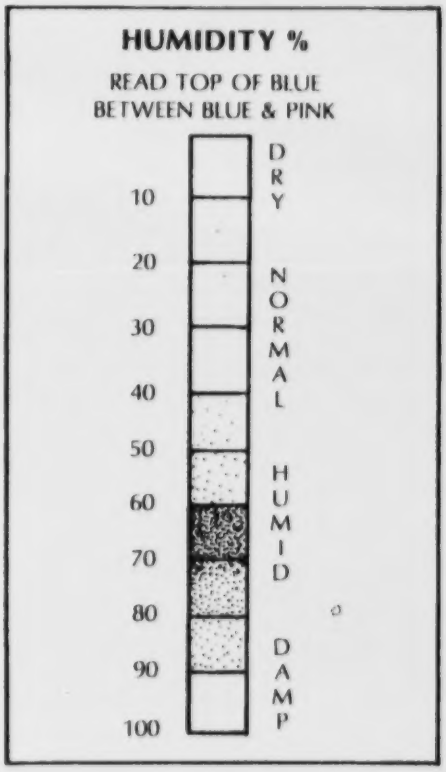

Figure 22 Humidity card.

Humidity Gadgets and Toys

Humidity gadgets and toys of all shapes and kinds are made using cobalt chloride paper. Have you seen this one?

Example:

cardboard donkey

tail made of string with cobalt chloride on it

The directions say:

donkey-tail blue . . . fair weather
donkey-tail pink . . . rain
donkey-tail swinging . . .windy
donkey-tail gone . . . hurricane

Type B. Hair Hygrometer

A commercial hygrometer has several hundred stretched human hairs built into it. Human hair is one of the most sensitive devices we have for showing humidity changes. Below are instructions for making a homemade *hair hygrometer* using one hair.

Materials

- a long, human hair
- a long, narrow board or heavy cardboard
- a small weight, such as a metal washer, or a medium-sized nail
- a 3 x 5 card or similar piece of stiff white paper
- a small nail or picture hook from which to hang the hair
- several screw eyes or staples
- a straight, thin wire about 15 cm or longer
- a light bulb or heater to dry the hair

Construction

1. Wash the hair thoroughly to remove its natural surface oils. (The surface oils inhibit the hair's response to moisture.)
2. Place a long, narrow board or cardboard against the wall or on a door or window frame at a convenient height.

3. Insert a nail or picture hook at the top of the board. Attach one end of the hair to the nail so that the hair will not slip.
4. Every few decimeters, insert a screw eye or drive a staple into the backing board and thread the hair through the openings. This keeps the hair from being blown too much in the wind.
5. To the bottom end of the hair fasten a small weight which is heavy enough to keep the hair hanging straight.
6. Attach a straight, thin wire to the hair above the weight. This is the pointer.
7. Put a staple over the thin wire at a point about 3 cm from the hair. This acts as a fulcrum.
8. Mount a white card or piece of paper behind the tip of the pointer on which calibration marks can be made. (See Figure 23.)

Calibration of the Hair Hygrometer

1. Wet the hair thoroughly. This stretches the hair to its greatest length.
2. While the hair is wet, mark the position of the pointer on the white card. This position represents 100% humidity.
3. Now thoroughly dry the hair by placing one or two light bulbs or a heater near it.

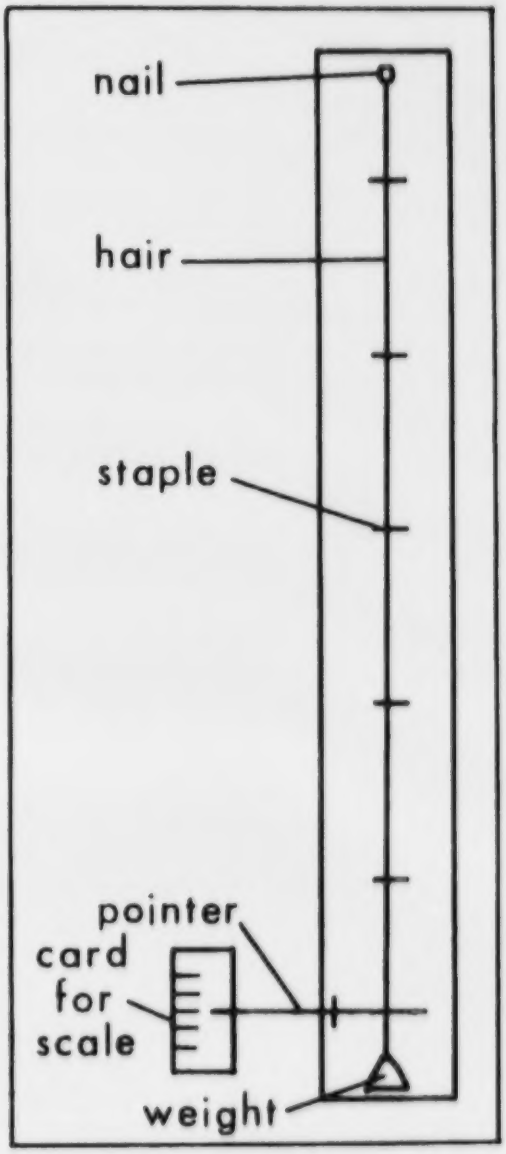

Figure 23 Homemade hair hygrometer.

4. When the hair is very dry, again mark the position of the pointer on the white card. This position can be called 0% humidity.
5. Mark lines between 100% and 0% positions to indicate intermediate relative humidities.

Use of the Hair Hygrometer

When the air is moist, the hair will stretch and the pointer will approach the 100% line. When the air is dry it will move toward the 0% line. If you have a commercial hygrometer mounted on your classroom wall, you can compare your hair hygrometer readings with it to see if both agree.

Type C. Wet-and-Dry-Bulb Hygrometer

A *wet-and-dry-bulb hygrometer* consists of two thermometers mounted near each other. One thermometer has a damp cloth around its bulb and is called the *wet-bulb thermometer.* The other thermometer is left exposed to the air and is called the *dry-bulb thermometer.*

Materials

- 2 thermometers
- a backing board to fit behind the thermometers
- a woven wick or a few square centimeters of knitted cloth
- a very small jar or bottle for water
- a small platform or other means of holding the water jar

Construction

1. Mount the two thermometers on the backing board so that the calibrations on the thermometers are clearly visible.
2. Make a small platform or other holder to keep a small jar about 2 or 3 cm below one of the thermometers. Put water in the jar.

3. Use a ready-made wick or make one by rolling or sewing knitted cloth into a narrow tube. Slip one end of the wick over the bulb of the thermometer. The other end hangs into the water in the jar. This water moves up the wick to the bulb.
4. Make a small barrier of cardboard of similar material between the two thermometers so that air from the wet bulb does not move across the dry bulb. (See Figure 24.)

Use of Wet-and-Dry-Bulb Hygrometer

1. Let a natural breeze or air from a fan blow across the two thermometers. The breeze should blow in a direction so that air coming from the wet bulb does not blow across the dry bulb. Why?
2. Read the temperature on both thermometers. One of the thermometers will register a lower temperature than the other. Which one? Why is that one lower?
3. Continue to blow air over the thermometers until the lower one does not drop any further in temperature. Do you know why or when the temperature will stop decreasing?
4. Using the reading from the two thermometers, find the relative humidity from the humidity table.

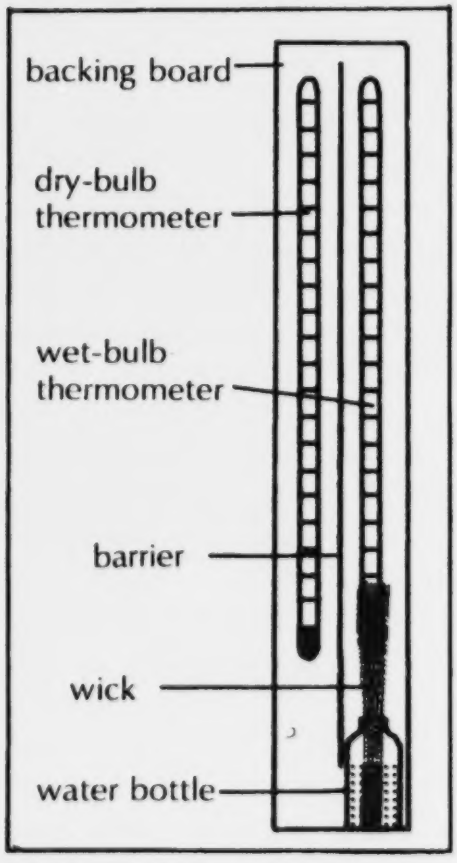

Figure 24 Wet-and-dry-bulb hygrometer.

Use of Relative Humidity Tables

1. On the vertical axis find the temperature of the dry-bulb thermometer.
2. On the horizontal axis find the number which is the *difference* between the temperature readings of the dry-bulb thermometer and the wet-bulb thermometer.
3. Where these two lines cross, the table gives the relative humidity for the air you measure.
4. Use whichever table matches the kind of thermometers you are using. Table 3 is for Celsius thermometers. Table 4 is for Fahrenheit thermometers.

Table 3 Relative Humidity (Celsius)

Dry-Bulb Temperature (C°)	Degrees Difference Between Wet- and Dry-Bulb Thermometers									
	1	2	3	4	5	6	7	8	9	10
10	88	77	66	55	44	34	24	15	6	0
12	89	78	68	58	48	39	29	21	12	0
14	90	79	70	60	51	42	34	26	18	0
16	90	81	71	63	54	46	38	30	23	15
18	91	82	73	61	57	49	41	34	27	20
20	91	83	74	66	59	51	44	37	31	24
22	92	83	76	68	61	54	47	40	34	28
24	92	84	77	69	62	56	48	43	36	31
26	92	85	78	71	64	58	51	46	39	34
28	93	85	78	72	65	58	53	48	42	37
30	93	86	79	73	67	61	55	50	44	39
32	93	86	80	74	68	62	57	51	46	41
34	93	87	81	75	69	63	58	53	48	43
36	94	87	81	75	70	64	59	54	50	48

Table 4 Relative Humidity (Fahrenheit)

Dry-Bulb Temperature (°F)	Degrees Difference Between Wet- and Dry-Bulb Thermometers																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
50	93	87	80	74	67	61	55	49	43	38	32	27	21	14	10	5	0	0
55	94	88	82	76	70	64	59	54	49	43	38	33	28	23	18	14	10	5
60	94	89	84	78	73	68	63	58	53	48	44	39	34	30	26	22	18	14
65	95	90	85	80	75	70	65	61	56	52	48	44	39	35	31	28	24	20
70	95	90	86	81	77	72	68	64	60	55	52	48	44	40	36	33	29	26
75	95	91	87	82	78	74	70	66	62	58	55	51	47	44	40	37	34	31
80	96	92	87	83	79	75	72	68	64	61	57	54	51	47	44	41	38	35
85	96	92	88	84	80	77	73	70	66	63	60	56	53	50	47	44	41	38
90	96	92	88	85	81	78	75	71	68	65	62	59	56	53	50	47	44	41
95	96	93	89	96	82	79	76	72	69	66	63	60	58	55	52	49	47	44
100	96	93	89	86	83	80	77	73	70	68	64	62	59	56	54	50	49	46

Type D. Sling Psychrometer

The *sling psychrometer* is the same instrument as the wet- and-dry-bulb wall hygrometer except that

1. in the wall hygrometer, the thermometers stay in one place and the air moves.
2. in the sling psychrometer, the two thermometers are swung through the air.

Materials

- a commercial sling psychrometer

Note: You can make your own sling psychrometer, but it is not recommended because homemade fastenings sometimes let thermometers slip off during the twirling.

Use of the Sling Psychrometer

1. Wet the wick on the wet-bulb thermometer.
2. Swing the instrument for about 3-5 minutes in the air. Read the temperature of the two thermometers. (See Figure 25.)
3. Use the humidity tables to determine the relative humidity.

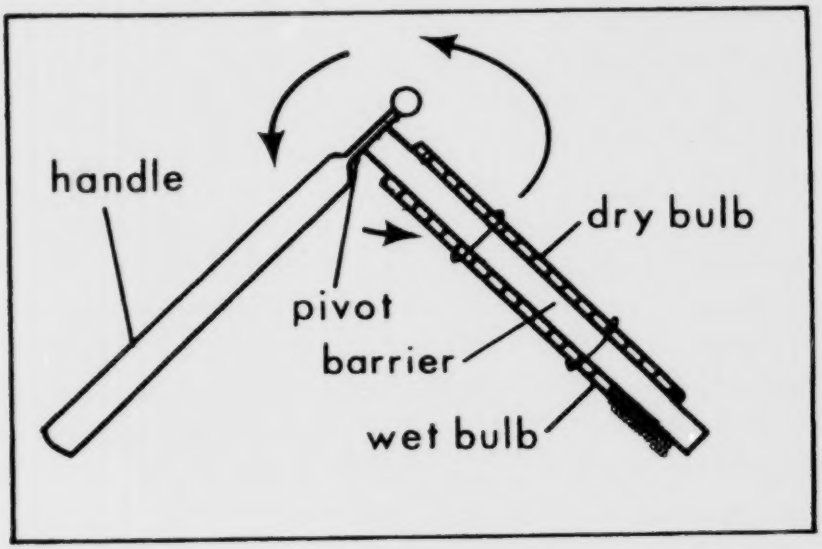

Figure 25 Sling Psychrometer.

Type E. Human Sensitivities

The most valuable humidity instrument we have is our human sensitivity to moisture in the air. Even though we cannot see water vapor with our eyes, our other senses detect it.

On days of high humidity, we say the air feels "muggy." When it is cold and damp we shiver, not so much from the cold as from the moisture in the air. If it is dry and cold, we enjoy crisp weather. On steamy days, we collapse

in our chairs and complain, "it isn't the heat, it's the humidity." In very dry places the human body can withstand much higher temperatures without feeling uncomfortable.

Some people with certain muscular or bone diseases are very sensitive to moisture in the air. They can sometimes sense as little as a 10% change in humidity by the discomfort which damp air brings to them. You can train yourself to notice moisture in the air.

After you get your classroom humidity instrument made, get into the habit of "feeling" the air. Make an estimate of what you think the humidity is. Then read the humidity from the classroom instrument to compare with your estimation. You may become very skilled at estimating relative humidity.

Barometers

Barometers measure the pressure of the air. Commercial barometers are of two types.

Type A. Aneroid Barometer

In the *aneroid barometer*, air pushes on one wall of a vacuum chamber. The change in the size of the chamber is registered on a dial.

Type B. Mercury Barometer

In the *mercury barometer*, changes in air pressure cause changes in the height of the mercury column. You made a barometer of this type in physical science.

There seems to be no simple way of measuring air pressure in a back yard weather station. The vacuum specifications and construction of an aneroid barometer are too complex to make in the classroom. The mercury barometer is too awkward and too difficult to transport to, or keep in, your weather station. See Problem 20, Barometer Project, in the physical science section.

Meanwhile, to get air pressure readings to correlate with your weather station data, use your *classroom barometer.*

Atmospheric Observations

Visibility is the distance through the air that we can see. Substances in the air decrease visibility. The substances may be particles, gases, or tiny droplets of water, as in fog or haze.

Materials

- map of your area
- compass

Directions

1. Sighting from your weather station, select 3 or 4 sight lines in widely differing directions.
2. Along each sight line, select 2 or 3 landmarks at different distances. Try to select the furthest landmark 12 or more miles away.
3. Using the compass and map of your area, determine the direction and distance of each landmark.
4. Each day when you take your weather measurements, sight your chosen landmarks. Record the visibility according to the letter key given in Table 5.
5. Use the number key in Table 5 to describe the appearance of the atmosphere. Numbers 6 to 8 are left blank so that you can add any descriptions of your own.
6. In the example given in Table 5, observation of Koko Head was made on October 4. On that date, Koko Head was *not clearly visible* (b) and there was a *blue-gray haze* (2) in the air. These observations were recorded as b/2.
7. Summarize your daily visibility observations on your weather station data sheet.
8. Save your visibility observation data for later air pollution studies.

Table 5 Visibility and Atmospheric Appearance

			Visibility Key a = clearly visible b = not clearly visible c = not visible			Description Key 1 = orange haze 2 = blue-gray haze 3 = heavy cloud cover 4 = white billowy clouds 5 = dark storm clouds 6 = 7 = 8 =			
			Dates of Observations						
Selected Landmark	Compass Direction	Distance	Oct 4						
Koko Head	SE	6 miles	b/2						

Optional

Prepare a photographic record of each observation.

Dustfall Jar

The *dustfall jar* can be used to measure the amount of large particles in the air. As dust settles out of the air, it falls into the jar and is trapped in the water. After the dustfall jar has been exposed to the air for a period of time, the dust can be filtered out of the water and the mass of the particles determined.

Materials

- a wide-mouthed gallon jar
- a tablespoon of Clorox
- a graduated cylinder (100 or 250 ml)
- balance
- funnel
- Whatman #42 or #1 filter paper

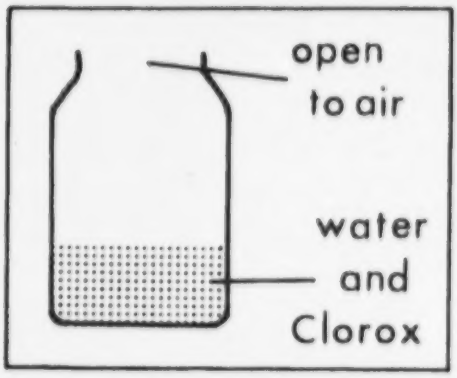

Figure 26 Dustfall jar.

Directions

1. Thoroughly clean a gallon jar.
2. Fill the jar ¼ full with water and mark the level. The amount of water is not critical since only the mass of the particles trapped will be measured.
3. Add about 1 tablespoon of Clorox to the water to inhibit algae growth. (See Figure 26.)

Use of the Dustfall Jar

1. Place the jar on the exposed top of your weather station. Record the date. Let the jar stand for 30 days. If the water level falls below the mark, add more water.
2. After 30 days, remove and discard leaves, paper, and other large objects which may have fallen into the jar.
3. Filter out the particles and determine the mass as follows:

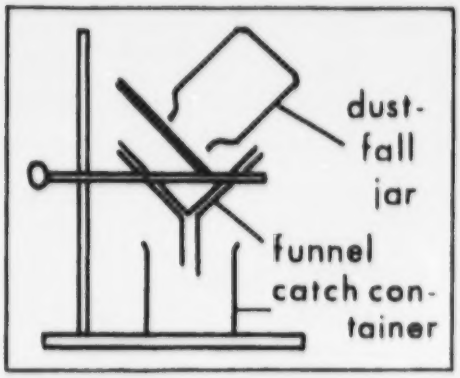

Figure 27 Filtering particles from dustfall jar.

   a. Determine and record the mass of a filter paper.
   b. Assemble filter paper, funnel, and ring stand as shown in Figure 27.
   c. Filter out the particles.
   d. Dry the filter paper and particles. (Dry in an oven or under a bright light or in the sun, but avoid losing any particles.)
   e. Determine and record the mass of the dry filter paper plus the particles.
   f. Calculate the *mass of the particles.* Subtract the mass of the filter paper from the mass of the filter paper and particles.

$$\begin{matrix}\text{Mass of}\\ \text{Filter Paper}\\ \text{and Particles}\end{matrix} - \begin{matrix}\text{Mass of}\\ \text{Filter Paper}\end{matrix} = \begin{matrix}\text{Mass of}\\ \text{Particles}\end{matrix}$$

4. Save your measurements and observations for later air pollution studies.

Sticky-Tape Can

Windblown particles that are too small to settle out of the air may be blown for long distances. The *sticky-tape can* provides a vertical surface upon which small windblown particles may be trapped.

Materials

- compass
- tuna fish can open at both ends
- adhesive strip (Fasson paper or contact paper), 3 cm wide and long enough to fit around the can
- rubber cement or glue
- hammer
- nail about 4 cm long
- clear acrylic spray or lacquer
- hand lens

Construction

1. Prepare the can to hold the sticky-tape.
   a. Cut the tuna can open down the side.
   b. Make a hole through both cut ends of the can large enough for the nail to slip through easily. (See Figure 28.)

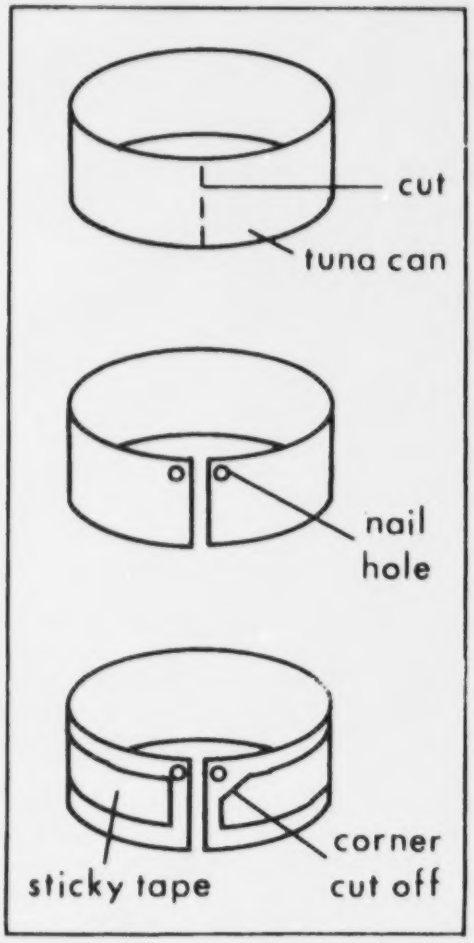

Figure 28 Construction of sticky-tape can.

2. Prepare the sticky-tape.

   a. Cut a 3 cm wide strip of the sticky-tape long enough to fit around the can.

   b. Glue the sticky-tape (sticky side out) to the can. Leave the protective liner on the sticky-tape.

   c. Cut off the top corner of one end of the sticky-tape. This will indicate which is the top of the tape when it is later removed from the can.

3. Slip the can around the post of your weather station or a nearby post.

   a. Using a compass, adjust the can so that the cut ends line up with magnetic north.

   b. Hammer a nail through the holes in the can into the post. The nail will hold the can off the ground and prevent it from changing direction. (See Figure 29.)

      Note: The can should be at least ½-meter above the ground so that water does not splash on it.

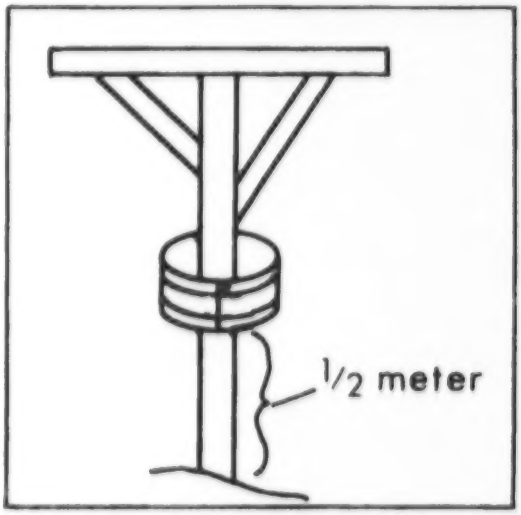

Figure 29 Sticky-tape can on field station.

Use of the Sticky-Tape Can

1. Remove the protective liner from the sticky-tape. Expose the tape for about seven days.
2. After the exposure time, spray the sticky-tape heavily with clear acrylic to fix the collected particles to the paper. Allow the spray to dry.
3. Remove the tape and flatten it out.

   a. Fold or otherwise divide the sticky-tape into 8 equal sections.

b. Beginning with the north end of the tape (the end with the corner cut off), mark the 8 compass points on the tape. (See Figure 30.)

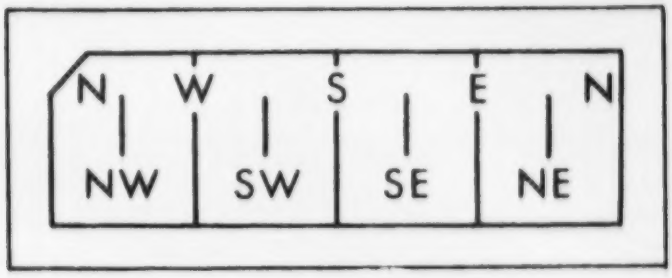

Figure 30 Sticky-tape after exposure.

4. Observe and compare the relative amounts of particles which adhered to the sticky-tape from each direction.
5. Examine the particles with a hand lens. Try to determine what the particles are.
6. Record your observations. Save the sticky-tapes for later air pollution studies.

Detection of Gases in the Air

Some gases in the air can be detected using chemically treated materials. Some of the materials are listed in Table 6.

Table 6 Indicator Materials for Detection of Gases in Air

Gas	Indicator Material	Indicator Change	Length of Exposure
Nitrogen dioxide (NO_2)	NO_2-sensitive dyed fabric	Blue changes to pink, then beige	90 days
Sulfur dioxide (SO_2) and other "acidic soots"	Fine quality nylon hose (15 denier) mounted in slide holder	Fibers disintegrate	90 days
Ozone (O_3)	Rubber strips	Rubber cracks	7-14 days
	O_3-sensitive dyed fabrics	Dark gray fabric lightens to beige-gray	90 days
Acidic Soots	Clean, shiny metals (copper, silver coins)	Metal tarnishes	90 days

Materials

- indicator materials
- half-gallon milk carton
- string
- clear glass jar with a tight lid
- paraffin (optional)

Construction

1. Prepare a weatherproof shelter for the indicator materials. The shelter must allow free passage of air.
   a. Cut off and discard the top half of a half-gallon milk carton.
   b. Cut slits in at least 2 sides of the carton about 5 cm from the bottom and about 6 cm long.
   c. Make a cut about 1 cm long at each end of the slit to make a flap on each side of the carton.
   d. Bend each flap to allow air passage but keep rain out.
   e. Punch 2 holes in opposite sides of the carton about 2 cm from the bottom.
   f. Thread about 60 cm of string through the holes. The string is used to hang the carton and to support the indicator materials. (See Figure 31.)
2. Prepare the indicator materials.
   a. *Nitrogen dioxide.* Cut or obtain 2 cm x 4 cm pieces of AATCC Gas Fading Control Fabric.
   b. *Sulphur dioxide.* Attach 15-denier nylon hosiery or other sheer nylon to slide mounts.
   c. *Ozone.* Cut ozone-sensitive rubber into strips about 2 cm wide and 10 cm long. A wide rubber band may be substituted if necessary.

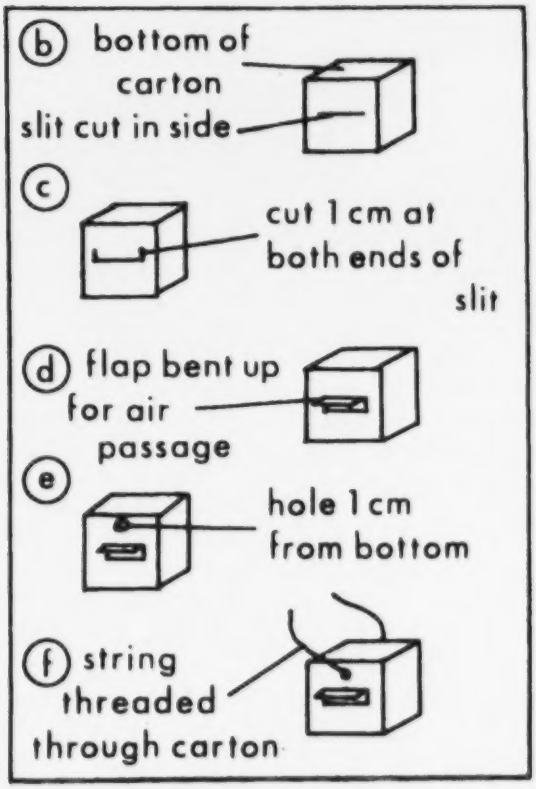
b bottom of carton
slit cut in side
c
cut 1 cm at both ends of slit
d flap bent up for air passage
e
hole 1 cm from bottom
f string threaded through carton

Figure 31 Construction of weatherproof shelter.

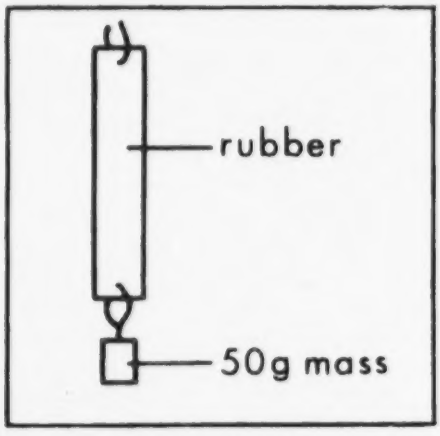

Figure 32 Stretched ozone-sensitive rubber.

Stretch the rubber material lengthwise by suspending a 50 g mass from the end of the rubber strip as shown in Figure 32.

d. *Acidic Soots.* Cut or obtain small pieces of copper metal. Also obtain several silver coins or pieces of silver metal. Clean the metals with dilute nitric acid or silver polish.

e. Prepare one set of controls for the class. Place one standard sample of each of the indicator materials in a dry, tightly sealed jar (jar may be further sealed with hot paraffin). Store the jar in a cool, dark place.

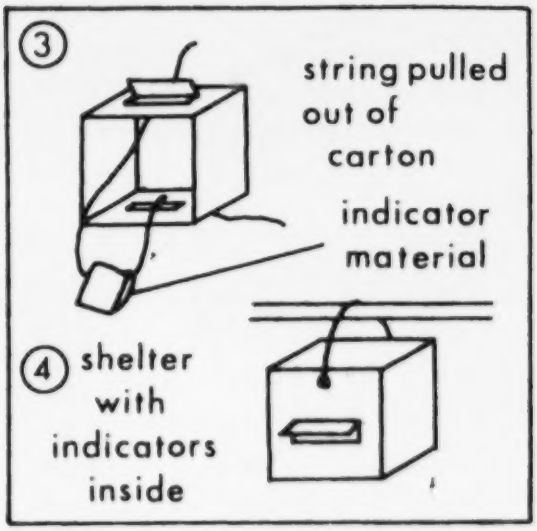

Figure 33 Indicator materials placed in shelter.

3. Attach the indicator materials to the string threaded through the weather-proof shelter.

   a. Pull the string out from inside the carton.

   b. Staple the indicator materials to the string.

   c. Pull the string from the outside of the carton, so that the attached indicator materials hang inside the carton.

4. Hang the shelter containing the indicator materials outdoors. The shelter may be attached to your weather station, a tree, or some other exposed place. (See Figure 33.)

Use of Indicator Materials

1. Expose the indicator materials in the shelter for 90 days (except the ozone indicator).

2. After 30 days, compare your test materials with the control. Describe and record any changes. Return the indicator material to the shelter.

3. After 60 days, compare your test materials with the control. Describe and record any changes. Return the indicator material to the shelter.
4. After 90 days, compare your indicator materials and observations with those of the other students in the class.
5. Rank the indicator materials in the class from *most* to *least* change. Record the data.
6. Save your data and observations for later air pollution studies.

pH of Rain Water

At least three gases, nitrogen dioxide, sulfur dioxide, and hydrogen sulfide, dissolve in rain water to form dilute acid solutions.

The presence of these gases in the air may cause rain water to become acidic. Acidity can be measured using pH indicator paper. pH paper is a type of indicator paper used to measure the acidity of liquids. A stirring rod is dipped into the liquid, then touched to the pH paper. The color of the wet pH paper is then compared to a pH number chart. Numbers between 1 and 6 indicate an *acid* with 1 being the strongest acid. Distilled water has a pH of 7 and is said to be *neutral*. A ph of 8-14 is described as alkaline. The pH scale is shown in Figure 34.

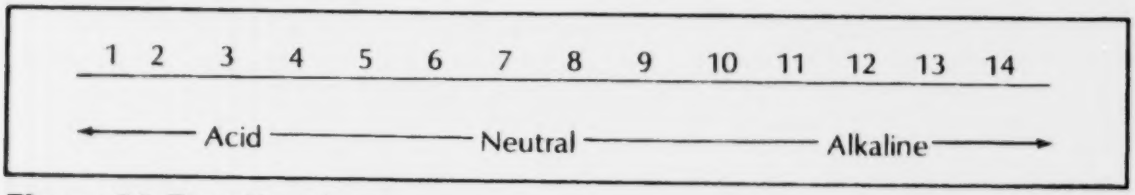

Figure 34 The pH scale.

Materials

- pH paper, e.g., Baker's dual tint paper
- stirring rod

Use of pH Paper

1. Have pH paper ready to use the next time it rains.
2. When it first begins to rain, *immediately* go outside and catch the first few drops of rain.
3. Wet the pH paper with the rainwater. Compare your pH paper with the pH scale. Determine and record the pH reading.
4. Compare the pH readings of the first raindrops with those 15-30 minutes later, if the rain lasts that long.
5. Compare the pH readings of the first raindrops of the rains on different days.

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